OUTCOME OF ENDODONTICALLY TREATED TEETH DIAGNOSED WITH "CRACKED TOOTH"

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This is to certify that the Master's thesis of

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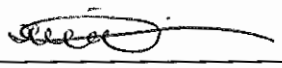

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minimum of 12 months after treatment, subjects were asked to return for a follow-up clinical and radiographic examination. The endodontic outcome was based on clinical follow-up examination results and radiographic PAI scores as determined by 3 calibrated board certified endodontists. The proportion of teeth diagnosed as clinically asymptomatic were classified as functional. Survivability was based on whether the tooth was present.

Results: To date, 20 subjects (21 teeth) have been enrolled in the retrospective portion of the study. Nine subjects had ten teeth meeting inclusion criteria and were eligible for follow-up. Four subjects (4 teeth) could not be followed up. Three teeth were radiographically verified as extracted. Three teeth were followed up with a median follow-up time of 18.4 months. The healed rate among these three teeth was 33% and 66% were considered functional. When considering the three teeth that were followed up and the three teeth extracted together, the survival rate was 50%.

Conclusion: An interim analysis of this in-vivo outcome study revealed initial endodontically treated teeth, diagnosed with "cracked tooth", had an unfavorable outcome.

CHAPTER I: INTRODUCTION

Cameron first described the cracked tooth as an incomplete fracture of vital posterior teeth involving dentin and possibly pulpal tissues (1). According to the American Association of Endodontists, a cracked tooth is defined as an "incomplete, greenstick fracture that is initiated from the crown and extends subgingivally" (2). The overall incidence of patients with a cracked tooth referred to a private endodontic practice over a six year period was 9.7% in a population of 8,175 patients (3). When diagnosed with reversible pulpitis and restored with a crown, 21% of these teeth were reported to require endodontic treatment within six months (3).

Fracture characteristics are variable. These fractures may extend through either marginal ridges, proximal surfaces, or both. If the central groove is included in the fracture the risk of pulpal and apical pathosis with apical extension of the fracture increases (4). It has been reported that 70.1% of fractures run in a mesiodistal direction, 18.8% in a buccolingual direction, and 11% in both directions (4). Fifty six percent involve the distal marginal ridge, 15% the mesial marginal ridge, and 29% involve both marginal ridges (5).

The cracked tooth is highly associated with discomfort. Patients often describe a momentary, sudden, sharp, lancinating pain that results in continuous tooth discomfort that can last from weeks to months. Upon examination, these teeth will typically test vital (6) but demonstrate greater pain upon biting. The pain may be explained by the hydrodynamic theory; as the fracture line opens and closes, the sudden movement of fluid within the dentinal tubules activates A delta fibers (7). Removing the fracture stops the fluid movement and is the basis for treatment (8). Tooth hypersensitvity is caused

CHAPTER II: REVIEW OF THE LITERATURE

In this review of literature, tooth and patient factors related to cracked teeth will be discussed. Diagnosing the cracked tooth and differential diagnosis will be presented as well. In addition, how to treat this condition and its prognosis will be detailed.

Tooth Factors

The literature has described several characteristics of teeth that increase their risk of undergoing a fracture. The tooth type and location in the dental arch play a prominent role. Mandibular molars are generally accepted as the most fracture prone. Their proximity to the temporo-mandibular joint exposes them to greater force during clenching, chewing, and other functional movements (10). However, it remains unclear as to which molar is the most affected. Mandibular first molars are the first teeth to erupt into the permanent dentition (11). Krell and others (2007) reported a 32% fracture rate of mandibular first molars (3). Mandibular second molars have also been described as the most affected teeth due to their terminal location in the arch. Cameron (1964) noted a 34% incidence of cracked mandibular second molars (1). Tan and others (2006) reported mandibular second molars having a relative risk of fracturing 4.9 times higher than other teeth (12). However, other authors have claimed maxillary molars to be equally affected (13). Their steep cuspal inclinations may concentrate stress, increasing the likelihood of fracture (14). Roh and others (2006) found a 33.8% incidence of cracked maxillary first molars (5).

Other tooth factors influencing fractures include a history of previous dental treatment, the type of treatment received and the size and category of restoration placed. In a study of 107 patients diagnosed with tooth fracture, 72% had previously

sharp line angle exists between the floor and wall of the preparation), usually run perpendicular to the dentinal tubules and progress toward the enamel/cementum exiting either supra or subginvgivally. Over time, repeated dynamic loading causes a fracture to occur (8). Fractures within non-restored and minimally restored teeth are typically vertical in nature, initiate in enamel, extend in a mesiodistal direction and run parallel to the dentinal tubules (17). Left untreated, the teeth are more likely to become non-restorable because as the crack progresses, it communicates with the pulp or periodontal tissues (8). All cusps may demonstrate pressure sensitivity when examined.

Many etiologies have been suggested for cracks discovered in restored teeth. Large and deep restorations adversely alter tooth strength. Cracks introduced during cavity preparation undergo fatigue failure over time resulting in defect propagation and eventual failure. Deep coronal dentin near the pulp has lower resistance to fatigue crack growth when compared to peripheral dentin. This is consistent with the increased density of dentinal tubules closer to the pulp (18). Cusp flexure, caused by occlusal load stress during mastication and repeated thermal expansion, can initiate microcrack formation (13). The properties of restorative materials; modulus of elasticity, hydration expansion, and thermal expansion coefficients, contribute to stress concentration and also play a role in tooth fracture. Amalgam and gold have higher thermal expansion coefficients compared to natural teeth. Resin composite also has a high thermal expansion coefficient and additionally undergoes 2-5% (by vol.) polymerization shrinkage. Thermocycling of teeth initiates dentin fractures at the dentinal enamel junction (DEJ) (16). High speed vibration generated during cavity preparation,

associated with more extensive fractures and provide a path for infection that may compromise the periodontium (11). Roh and Lee (2006) reported that 29.2% of cracked teeth had probing depths greater than 6mm, 29.2% had probing depths between 3-6mm, and 41.6% had normal probing depths (5). Teeth with existing deep isolated pre-treatment periodontal pockets had 4.9 times relative risk for fractures (12). Teeth with excursive interferences were 2.3 times more likely to fracture when compared to teeth without interferences (15). These interferences generate shear stress during both functional and parafunctional movements. Extractions, orthodontic treatment, over contoured restorations and other dental treatment may generate premature interferences through altered cusp fossae relationships. Fossae that concentrate stresses may be prone to fracture (8). The combination of multiple characteristics; parafunction, excursive interferences, and presence of restorations increase the likelihood of fracturing by 5.8 times (15).

Patient Factors

Patient factors such as gender, age, and oral habits also influence the incidence of cracked teeth. Early studies, including one in 1998 by Homewood, reported that females (63% F, 37% M) were more likely to present with cracked teeth (20). The author attributed this to their greater tendency to seek dental care and report pain when compared to men. More recent studies have found that gender does not play a role in the incidence of cracked teeth (11,12). Although there are no specific studies that discuss ethnic variations, these later studies were in Asian populations and may explain the differences from earlier findings. Cracked teeth are not commonly found in younger individuals. Their occurrence increases with age (5). Seo and others (2006)

breakdown of cracked tooth pain in patients; 54% presented with pain upon chewing, 32% pain to cold, 28% pain to heat, 18% had a generalized ache, 10% presented with cellulitis, 2% pain to sweet and 12% reported no pain (1). A more recent study by Seo and others (2012), noted 82.2% of patients were positive to bite testing, 51% experienced pain upon biting, 33.5% had moderate to severe cold sensitivity and 56.1% were negative to the percussion test (13). However, variable symptoms complicate the diagnosis (9). In a study of 32 patients presenting with diffuse longstanding orofacial pain eventually diagnosed with incomplete tooth fractured, none demonstrated the typical pain pattern associated with cracked teeth (22). Byrnjulsen and others (2002) found that fractured mandibular teeth can refer pain to adjacent teeth, the neck, ear, temporomandibular joint and muscles of mastication while fractured maxillary teeth infrequently refer pain to the mandible or auriculotemporal regions. Patients with cracked maxillary teeth may report feeling the discomfort in a location more mesial to the actual source. The longer a patient experiences pain prior to a diagnosis, the more diffuse the pain distribution (22). Patients symptomatic for at least 5 years experienced additional comorbidities such as headaches (22). Understanding a patient's symptoms aid the clinician in making a proper diagnosis. Early detection is key.

Following diagnosis, determination of the extent of the fracture is required to rule out pulpal and or periodontal involvement. The potential need for future treatment and prognosis should also be provided to patients (8). Ailor (2000) described in detail various techniques available to clinicians to improve fracture detection (16). Vision enhancers such as transillumination, magnification, loupes, and microscopes are useful in identifying the extent of a fracture. Vertical fractures in dentin cause light to bend,

diagnosis using transillumination (48%), dye staining (8%), microscoping examination (7%), and diagnostic surgery (8%) (13).

Periapical (PA) radiographs and cone beam computed tomography (CBCT) have been used to facilitate fracture detection. In general, PA radiographs have limited value for a number of reasons. They compress three dimensional anatomy into a two dimensional image. The image may be distorted, depending on the angle of the beam, and overlying anatomical features may obscure the area of interest (23). A PA radiograph can only detect extensive cracks (23). Additionally, bucco-lingual oriented cracks will be captured while mesiodistal ones can be missed. PA radiographs are however useful in excluding other pathoses such as dental caries (17) and the bone loss associated with fractures. Severe bone loss may take an average of 10.5 months to develop following tooth fracture (24). A limited field of view CBCT accurately produces three dimensional scans of the maxillofacial anatomy using much less radiation when compared to conventional computed tomography (25). A significant limitation of CBCT is image distortion caused by x-ray scatter and beam hardening generated by high density structures. The presence of metallic posts or restorations near the area of interest can make an accurate diagnosis unlikely (25). Currently, there are no studies that specifically evaluate cracked teeth using CBCT. However, there are studies evaluating vertical and horizontal root fractures using this technology. An in vivo study of 128 patients found the CBCT accurately confirmed the presence of a root fracture in 91.9% of cases compared to 48.1% with PA radiographs (26). This study also reported that PA radiographs had 26.3% sensitivity and 100% specificity while CBCT scans had 89.5% sensitivity and 97.5% specificity. In another study investigating

that begins in the root, extends buccolingually and may or may not involve the buccal and lingual surfaces of the crown. This break involves only root structure and patients will demonstrate minimal signs and symptoms until a periapical lesion appears on a radiograph. Virtually all vertical root fracture cases received previous endodontic treatment. In a study of teeth with longitudinal tooth fractures, 81.3% were diagnosed with cracked tooth, 13.1% with vertical root fracture, 3.7% with split tooth, and 1.9% as fractured cusp (13). Other possible diagnoses include reversible pulpitis, postoperative sensitivity, galvanic activity associated with amalgam restorations, hyperocclusion and neuropathic pain (9). Differential diagnoses should always be considered in order to make the correct diagnosis and render appropriate treatment.

Treatment

The primary goal of treatment for cracked teeth is to immobilize the fractured segments to prevent cusp flexure under occlusal load. When practical, a secondary goal is to establish the extent of the fracture in order to determine if endodontic or periodontal surgery is required (8). The following overview of treatment options has been described by Ailor (16): 1.) if a restoration is present, remove it, if the cusp breaks off, restore with an appropriate restorative material, 2.) if the cusp does not break off, place a tight fitting band, cement in place, and re-evaluate in two to four weeks, 3.) place a full crown as a definitive restoration, 4.) if symptoms persist, i.e. thermal sensitivity or necrosis, root canal therapy (RCT) will be needed, and 5.) if the fracture extends into the root beyond the attached gingiva, extraction may be indicated. The AAE provides additional guidelines (4): 1) RCT is provided only if a pulpal and apical diagnosis requires it, the presence and extent of the crack does not determine the need

Restorative options available to practitioners for fractured teeth include the placement of cuspal coverage amalgam alloys, direct or indirect composite resins, composite splints or a full coverage crowns. There are advantages and disadvantages to all methods. Homewood (1998) reported 93% success overlaying cusps with amalgam alloy. The other 7% of teeth in the study eventually required RCT (20). Amalgam is a material familiar to dentists. It is cost effective and remains available in most areas. It is claimed to be unaesthetic and does not adhere to tooth structure. Composite resin is an alternative direct restorative material available to clinicians. Opdam and others (2008) demonstrated a high success rate following placement of composite, only 7% of teeth required endodontic treatment and 5% were extracted (32). At 6 month follow-up: 75% of teeth were symptom free and 50% tested normal to cold and load application. At 7 years: 75% remained symptom free. In the same study, 6% of teeth restored without cuspal coverage failed on an annual basis, possibly due to loading of remaining cusps leading to stress and failure of the adhesive layer. No failures were reported for teeth with cuspal coverage for the 7 year duration of the study. Ninety percent of teeth treated with bonded composites maintained vitality over the long term (32). Cuspal coverage is therefore recommended when restoring fractured teeth with direct composite resin. Banerji and others (2014) recommend the use of the direct, supra-coronal, composite onlay splint. This splint serves as a diagnostic aid, provides pain relief, prevents fracture extension and allows occlusal clearance for a more definitive final restoration (33). Unlike traditional onlay preparations, tooth structure is not reduced. The 1.5mm thick splint is left flat in a supra occlusal position. However, prior to placement of this splint, patients must be carefully

Concerns with crowns include cost of treatment, loss of tooth vitality and increased difficulty in establishing access should the need for future endodontic treatment arise. For cracked teeth diagnosed with irreversible pulpitis, RCT followed by crown placement is the recommended treatment (4). In a study of 49 patients diagnosed with irreversible pulpitis, teeth had an 85% two-year survival rate. The remaining 15% required extraction (12).

Prognosis

The prognosis for a cracked tooth is dependent on the extent of the fracture (9). Cracks that do not extend to the pulp, run horizontally, involve a single marginal ridge, and/or do not extend more than three millimeters below the periodontium have a favorable prognosis once properly restored. Fractures involving both marginal ridges, that communicate with the pulp, and/or extend vertically through the floor of the chamber have a questionable prognosis. Teeth with unfavorable prognoses include those with complete mesiodistial fractures, teeth requiring gingivoplasty/alveoplasty to expose the extent of the fracture and the progression of a partial to a complete fracture (19). Early diagnosis and treatment is a key element for success. Prevention of future fractures to other teeth is also another important consideration (8). Occlusal adjustments, as discussed earlier, may lead to interferences on other teeth. Occlusal splints are recommended for patients that clench or brux to dissipate parafunctional forces. Curved internal line angles should be incorporated into cavity preparations and although not conservative, restorations incorporating cuspal coverage more evenly distribute stresses.

Summary

CHAPTER III: OBJECTIVE

The purpose of this in vivo study is to determine the outcome of teeth diagnosed with cracked tooth requiring initial NSRCT at a minimum of 12 months after receiving treatment using clinical and radiographic data. A secondary objective is to determine associated variables affecting the outcome of cracked teeth.

Additional information was collected during the initial evaluation regarding the cracked tooth to include tooth characteristics, diagnostic methods, and fracture location. Each subject was assigned a unique, sequential, subject number upon enrollment into the Endodontic Treatment Registry. The data were coded by assigning this number to all data collection sheets.

Once pre-treatment data were collected, NSRCT was initiated. Teeth were accessed under rubber dam isolation and information regarding crack location and extent were collected. No specified instrumentation, irrigation, or obturation technique was required. Access cavities were temporized using an appropriate material and subjects were referred to their general dentist for the permanent full cuspal coverage restoration.

For the retrospective portion of the study, a search of the Endodontic Registry was performed for subjects with 1) preexisting cracked tooth data collection forms and 2) eligible for a one year follow-up. All subjects of the prospective portion of the study already had completed cracked tooth data collection forms, thus only a search of subjects eligible for one year follow-up was performed. All qualifying records were examined radiographically to determine if the tooth was present (survived) or extracted. Subjects with teeth that survived were asked to return for a 12 month examination. The clinical examination was performed by NPDS residents and staff using a standardized and established endodontic clinical evaluation protocol. It included an evaluation of the tooth symptoms (percussion, palpation, periodontal probing, mobility, sensibility and tooth slooth testing). Radiographs were captured in a standardized manner and included one periapical radiograph at a minimum.

CHAPTER V: STATISTICAL ANALYSIS

Descriptive analysis was performed on the retrospective data. Prospective subjects data were not analyzed due to lack of meeting inclusion criteria. Future analysis will be performed using SPSS v15.0 (SPSS Inc, Chicago, IL) to include Fisher's Exact analysis and logistic regression to determine the influence of variables on healing. Odds ratios will be calculated on variables that have a sufficient number of subjects. An intraclass correlation coefficient will be performed to assess inter-examiner reliability.

CHAPTER VII: DISCUSSION

Currently, no studies address the question: what is the outcome of endodontically treated cracked teeth. The goals of this study are to answer that question and to further explore if variables such as visualization of the fracture, position of the fracture, or extent of the fracture has any effect on outcome. Other important variables include tooth position in the arch, probing depths and pre-existing restorations. This will be the first study to address this gap in knowledge.

A tooth survived if it was present at the time of follow-up examination. The current study determined that three of six teeth survived after one year, a 50% survival rate. This number is in contrast with the 85%, 2-year survival rate reported in the study by Tan & others (2006). However, that 2006 study did not determine the endodontic outcome. Prognostic factors deemed to decrease survivability were: teeth with multiple cracks, located most terminally in the arch, and had preexisting periodontal pockets. In the current study, there is insufficient data to analyze these factors.

The cracked tooth is not easily diagnosed, thus leading to cases that are extensive and less likely to survive and heal. Because they often are not diagnosed on periapical radiographs and CBCT scans, difficult to visualize clinically and patients report varying symptoms, cracks may become extensive over time (1, 19, 28). With extensive cracks, long standing biofilm may form with a greater depth of bacterial penetration (35). Endodontic disinfecting solutions have significantly less antibacterial effect on older biofilm compared to younger biofilm (36). This may contribute to poorer endodontic outcomes where cracks may have existed for a long period and patients do not seek treatment until endodontic treatment is required. Successfully treating the

CHAPTER VIII: CONCLUSION

For this interim analysis of retrospective data, endodontically treated teeth diagnosed with "cracked tooth" had an unfavorable outcome. This study will continue to collect both prospective and retrospective data for future analysis.

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